SIDLEY & AUSTIN

A PARTNERSHIP INCLUDING PROFESSIONAL CORPORATIONS

CHICAGO

LOS ANGELES

NEW YORK

WASHINGTON, D.C.

717 NORTH HARWOOD

DALLAS, TEXAS 75201

TELEPHONE 214 981 3300

FACSIMILE 214 981 3400

HONG KONG

LONDON

SHANGHAI

SINGAPORE

TOKYO

FOUNDED 1866

WRITER'S DIRECT NUMBER
(214) 981-3328

WRITER'S E-MAIL ADDRESS
pplap@sidley.com

October 26, 2000

Box Patent Application
Assistant Director for Patents
Washington, DC 20231

Re: U.S. Patent Application
ACTUATOR USING DIPPLACEMENT ELEMENT
By: Shinya MATSUDA, Takashi MATSUO, and Masayuki UEYAMA
Attorney Docket: 15162/02660

Dear Sir:

Enclosed for filing are the following papers relating to ACTUATOR USING DIPPLACEMENT ELEMENT, Shinya MATSUDA, Takashi MATSUO, and Masayuki UEYAMA, inventors:

(1) Specification (25 pages, including 12 claims and an abstract);

(2) Executed Declaration and Power of Attorney (8 pages);

(3) Formal Drawings (14 sheets);

(4) Transmittal letter (1 page), with PrintEFS Patent Application Bibliographic Data (2 pages);

(5) Transmittal letter (1 page), with Copy of Certified Priority Document (35 pages);

(6) Assignment of the invention to Minolta Co., Ltd. (2 pages), with Recordation Form Cover Sheet (1 page - in duplicate); and

Assistant Director for Patents
Box Patent Application
October 26, 2000
Page 2

(7)   Preliminary Amendment.

The amount of the filing fee is calculated below:

FEE	NO. FILED	NO. EXTRA*	FEE FOR SMALL ENTITY		OR	FEE FOR OTHER THAN SMALL ENTITY	
			RATE	FEE	OR	RATE	FEE
Basic Fee				$355.00	OR		$710.00
Total Claims	12 – 20 =	0	x $ 9.00 =	$ 0	OR	x $ 18 =	$ 0
Independent Claims	2 – 3 =	1	x $ 40.00 =	$ 0	OR	x $ 80 =	$ 0
Multiple Dependent Claims Presented	0 – 0 =	0	+ $135 .00 =	$ 0	OR	+ $270 =	$ 0
			TOTAL	$ 0	OR	TOTAL	$710.00

*If the difference in Column 1 is less than zero, enter "0" in Column 2.

Please charge the required fee ($710.00 for the application filing fee) to Sidley & Austin's Deposit Account No. 18-1260. If additional fees are due, please charge any fees during the pendency of this application (other than the issue fee) to Deposit Account No. 18-1260. Please credit any overpayment to Deposit Account No. 18-1260. This transmittal letter is being filed in duplicate.

All correspondence is to be directed to the address associated with the customer number 24367.

Respectfully submitted,

James W. Williams
Registration No. 20,047
Attorney for Applicants

JWW/tjf

Enclosures

Attorney Docket No.: 15162/02660

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re

U.S. Application of: Shinya MATSUDA, Takashi MATSUO, and
                        Masayuki UEYAMA

For: ACTUATOR USING DIPPLACEMENT ELEMENT *being*
                        amended to ACTUATOR USING DISPLACEMENT
                        ELEMENT

U.S. Serial No.   Not yet assigned

Filed: Concurrently

Group Art Unit: To be determined

Examiner: To be determined

Box Patent Application
Assistant Director for Patents
Washington, DC 20231

Dear Sir:

<table>
<tr><td>Express Mail Mailing Label No.: EL195379270US</td></tr>
<tr><td>Date of Deposit: OCTOBER 26, 2000</td></tr>
<tr><td>I hereby certify that this paper or fee is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 C F R. § 1 10 on the dated indicated above and is addressed to the Assistant Director for Patents, Box Patent Application, Washington, DC 20231</td></tr>
<tr><td>DERRICK T. GORDON
Name of Applicant, Assignee, or Registered Representative</td></tr>
<tr><td>Signature</td></tr>
<tr><td>OCTOBER 26, 2000
Date of Signature</td></tr>
</table>

TRANSMITTAL OF PrintEFS PATENT APPLICATION BIBLIOGRAPHIC DATA

Submitted herewith is bibliographic data (2 pages) for the above-identified application, in the PrintEFS Version 1.0.1 program format, which recites the title as corrected by the Preliminary Amendment.

Respectfully submitted,

James W. Williams
Registration No. 20,047
Attorney for Applicants

JWW/tjf

SIDLEY & AUSTIN
717 N. Harwood, Suite 3400
Dallas, Texas 75201-6507
Direct: (214) 981-3328
Main: (214) 981-3300
Facsimile: (214) 981-3400

October 26, 2000

INVENTOR INFORMATION

Inventor One Given Name:: Shinya
Family Name:: MATSUDA
Postal Address Line One:: Minolta Co., Ltd., Osaka Kokusai Bldg.,
Postal Address Line Two:: 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku,
City:: Osaka-Shi
State or Province:: Osaka
Country:: JAPAN
Postal or Zip Code:: 541-8556
City of Residence:: Takarazuka-Shi
State or Province of Residence:: Hyogo-Ken
Country of Residence:: JAPAN
Citizenship Country:: JAPAN
Inventor Two Given Name:: Takashi
Family Name:: MATSUO
Postal Address Line One:: Minolta Co., Ltd., Osaka Kokusai Bldg.,
Postal Address Line Two:: 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku,
City:: Osaka-Shi
State or Province:: Osaka
Country:: JAPAN
Postal or Zip Code:: 541-8556
City of Residence:: Itami-Shi
State or Province of Residence:: Hyogo-Ken
Country of Residence:: JAPAN
Citizenship Country:: JAPAN
Inventor Three Given Name:: Masayuki
Family Name:: UEYAMA
Postal Address Line One:: Minolta Co., Ltd., Osaka Kokusai Bldg.,
Postal Address Line Two:: 3-13, 2-Chome, Azuchi-Machi, Chuo-Ku,
City:: Osaka-Shi
State or Province:: Osaka
Country:: JAPAN
Postal or Zip Code:: 541-8556
City of Residence:: Takarazuka-Shi
State or Province of Residence:: Hyogo-Ken
Country of Residence:: JAPAN
Citizenship Country:: JAPAN

CORRESPONDENCE INFORMATION

Correspondence Customer Number:: 24367
Name Line One:: James W. Williams
Telephone One:: (214) 981-3328
Fax One:: (214) 981-3400
Electronic Mail One:: pplap@sidley.com
Telephone Two:: (214) 981-3300
Electronic Mail Two:: jwilli09@sidley.com

APPLICATION INFORMATION

Title Line One:: ACTUATOR USING DISPLACEMENT ELEMENT
Total Drawing Sheets:: 14
Formal Drawings?:: Yes
Application Type:: Utility
Docket Number:: 15162/02660
Secrecy Order in Parent Appl.?:: No

REPRESENTATIVE INFORMATION

Representative Customer Number:: 24367

PRIOR FOREIGN APPLICATIONS

Foreign Application One:: 11-312965
Filing Date:: 11-02-1999
Country:: JAPAN
Priority Claimed:: Yes

Source:: PrintEFS Version 1.0.1

Attorney Docket No.: 15162/02660

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re

U.S. Application of: Shinya MATSUDA, Takashi MATSUO, and
                        Masayuki UEYAMA

For: ACTUATOR USING DIPPLACEMENT ELEMENT
                        being amended to ACTUATOR USING
                        DISPLACEMENT ELEMENT

U.S. Serial No.   Not yet assigned

Filed: Concurrently

Group Art Unit: To be determined

Examiner: To be determined

Box Patent Application
Assistant Director for Patents
Washington, DC   20231

Dear Sir:

PRELIMINARY AMENDMENT

Please amend the above identified U.S. patent application as follows:

IN THE TITLE:

Please delete "ACTUATOR USING DIPPLACEMENT ELEMENT" and insert --ACTUATOR USING DISPLACEMENT ELEMENT--.

Attorney Docket No.: 15162/02660

REMARKS

This Preliminary Amendment is being filed to correct a typing error in the title of the invention.

This Preliminary Amendment does not increase the number of independent claims, does not increase the total number of claims, and does not present any multiple dependency claims. Accordingly, no fee based on the number or type of claims is currently due. However, if a fee, other than the issue fee, is due, please charge this fee to Deposit Account No. 18-1260.

Respectfully submitted,

James W. Williams
Registration No. 20,047
Attorney for Applicants

JWW/tjf

SIDLEY & AUSTIN
717 N. Harwood
Suite 3400
Dallas, Texas 75201-6507
Direct: (214) 981-3328
Main: (214) 981-3300
Facsimile: (214) 981-3400

October 26, 2000

2

ACTUATOR USING DIPPLACEMENT ELEMENT

This application is based on Patent Application No. 11-312965 filed in Japan, the content of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

5 Field of the Invention

The present invention relates to an actuator using a displacement element such as a piezoelectric element or the like.

Description of the Related Art

In recent years, actuators have been proposed having two displacement elements such as a piezoelectric element or the like are arranged with their displacement directions set at a predetermined angle (e.g., 90°). In this actuator, an alternating current voltage signal having a specific phase difference drives each displacement elements such that a drive member provided at the intersection point of the displacement elements moves in an elliptical path. This drive member abuts a driven member, and rotates or moves the driven member in a specific direction. Such an actuator is referred to as a truss-type actuator.

The operating principle of the general truss-type actuator is described below with reference to FIG. 15. FIG. 15 shows a truss-type actuator pressed against a rotor (driven member) 40 with a specific pressure F via a spring 41. In FIG. 15, μ represents the friction coefficient. The voltage or resulting displacement applied to the first piezoelectric element (displacement element) 10 and the second piezoelectric element (second displacement element) 10' is shown in FIG. 16. When sine wave voltages of different phase, as shown in FIG. 16, are applied to the first piezoelectric element 10 and the second piezoelectric element 10', the first

piezoelectric element 10 and the second piezoelectric element 10' are displaced in a sinusoidal wave-like fashion in accordance therewith. As a result, a tip member (drive member) 20 linked to the first piezoelectric element 10 and the second piezoelectric element 10' moves elliptically (including circular movement).

When the frequency of the sine wave voltage applied to the first piezoelectric element 10 and the second piezoelectric element 10' exceeds a predetermined value and the tip member 20 rotates at faster speed, the actuator itself cannot follow the displace the tip member 20 due to the force applied by the spring 41, and the tip member 20 is temporarily separated from the surface of the rotator 40 (intermittent contact). The tip member 20 moves in a direction opposite to a specified direction while the tip member 20 is separated from the surface of the rotor 40, so as to cause the rotor to rotate. This state is shown in FIGS. 17a~17e.

FIGS. 17a and 17e show the first piezoelectric element 10 and second piezoelectric element 10' both extended, with the tip member 20 in contact with the surface of the rotor 40. FIG. 17b shows the first piezoelectric element 10 contracted and the second piezoelectric element 10' extended, with the tip member 20 separated from the surface of the rotor 40. FIG. 17c shows the first piezoelectric element 10 and the second piezoelectric element 10' both contracted, with the tip member 20 separated from the surface of the rotor 40. FIG. 17d shows the first piezoelectric element 10 extended and the second piezoelectric element 10' contracted, with the tip member 20 in contact with the surface of the rotor 40 when the actuator overtakes the movement of the tip member 20. As can be understood from FIGS. 17a~17e, the rotor 40 is rotated by the repeated contact with and separation from the surface of the rotor 40 by the tip member 20.

When the amount of displacement of the first piezoelectric element 10 and the second piezoelectric element 10' is small and the amount of displacement of the tip member (drive member) 20 is less than several micrometers, a normal contact state arises between both the tip member 20 and the rotor 40 due to the elasticity of the materials of the tip member 20 and the rotor 40. In this instance, in essence disadvantages arise since the tip member 20 must separate from the surface of the rotor 40 and return in a specific direction so as to result in a reduction in speed of the movement of the rotor 40 due to the frictional force arising between both members, or the rotor 40 returns in the opposite direction in conjunction with the tip member 20 so as to reduce the output of the actuator. This phenomenon becomes more pronounced as the force exerted by the spring 41 increases.

OBJECTS AND SUMMARY

In view of the aforesaid disadvantages, an object of the present invention is to provide an improved actuator.

A further object of the present invention is to provide an actuator having high drive efficiency by driving at optimum drive conditions even when the amount of displacement of the displacement element is small.

These and other objects are attained by one aspect of the present invention providing an actuator comprising:

a displacement element which produces a specific displacement;

a drive member connected to one end of the displacement element and which transfers the displacement of the displacement element to a driven member;

a stationary member which supports the other end of the displacement element;

a compression member which presses the drive member against the driven member; and

a drive circuit for driving the displacement element when the drive member and the driven member are in a state of intermittent contact, and under conditions near the condition of transition from the intermittent contact state to a normal contact state.

In the actuator, when the spring constant of the compression member is designated $k1$, the combined spring constant of the displacement element and the drive member is designated $k2$, the spring constant of the driven member is designated $k3$, the amount of displacement of the displacement element is designated $X0$, and the compression force applied by the compression member is designated Nt, it is desirable that the following relationship is satisfied:

$$Nt = X0(1/(1/k2 + 1/k3) - 1/(1/k1 + 1/k2 + 1/k3))$$

It is further desirable that the displacement element is driven at a resonance frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and features of the present invention will become apparent from the following description of the preferred embodiments thereof taken in conjunction with the accompanying drawings, in which:

FIG. 1 shows the structure of a laminate-type piezoelectric element;

FIG. 2 illustrates the relationship between the displacement (amount of distortion) of the piezoelectric element and the strength of the

-4-

electric field generated between each electrode in the laminate-type piezoelectric element;

FIG. 3 shows the structure of a truss-type actuator using a laminate-type piezoelectric element;

FIG. 4 shows the block structure of the drive circuit;

FIG. 5a shows the path of the drive member of the actuator when the amplitudes of the drive signals applied to two piezoelectric elements are equal and the phase difference is 0 degrees;

FIG. 5b shows the path of the drive member of the actuator when the amplitudes of the drive signals applied to two piezoelectric elements are equal and the phase difference is 45 degrees;

FIG. 5c shows the path of the drive member of the actuator when the amplitudes of the drive signals applied to two piezoelectric elements are equal and the phase difference is 90 degrees;

FIG. 5d shows the path of the drive member of the actuator when the amplitudes of the drive signals applied to two piezoelectric elements are equal and the phase difference is 180 degrees;

FIG. 6a shows the path of the tip member when is under no load and a drive voltage of 30 V is applied;

FIG. 6b shows the path of the tip member when is under no load and a drive voltage of 40 V is applied;

FIG. 6c shows the path of the tip member when is under no load and a drive voltage of 50 V is applied;

FIG. 6d shows the path of the tip member when is under no load and a drive voltage of 60 V is applied;

FIG. 6e shows the path of the tip member when is under no load and a drive voltage of 70 V is applied;

FIG. 6f shows the relationship between the drive voltage and the diameter (displacement amount) of the path of the tip member;

FIG. 7 shows the relationship between the compression force applied by the spring of the actuator, and the contact interval between the tip member and the rotor;

FIG. 8 shows the relationship between the speed (rotation) and load on the rotor in the actuator;

FIG. 9 shows the actuator output characteristics (load-to-drive efficiency characteristics);

FIG. 10 shows the elastic contact model generating elastic deformation in the contact area of the tip member and the rotor in the actuator;

FIG. 11 shows the relationship between the displacement of the piezoelectric element and the drive force generated thereby in the elastic contact model;

FIGS. 12a, 12b, 12c, 12d show the deportment when the piezoelectric element extends and contracts in the elastic contact model;

FIG. 13 shows the relationship between the displacement of the piezoelectric element and the compression force in each state in the elastic contact model;

FIG. 14 shows the structure of another embodiment of a truss-type actuator;

FIG. 15 shows the voltages applied to the two piezoelectric elements of the actuator, and the displacement resulting therefrom;

FIGS. 17a, 17b, 17c, 17d, 17d, 17e illustrate the principle of rotating the rotor by an actuator.

In the following description, like parts are designated by like reference numbers throughout the several drawings.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the actuator of the present invention is described hereinafter. First, FIG. 1 shows the structure of a laminate-type piezoelectric element used as a displacement element of an actuator. As shown in FIG. 1, the laminate-type piezoelectric element 10 comprises alternating layers of a plurality of ceramic thin plates 11 having the voltage characteristics of PZT or the like, and electrodes 12 and 13, each ceramic thin plate 11 and electrode 12 and 13 being fixedly attached by adhesive or the like. The electrodes 12 and 13 arranged in every second layer are respectively connected to a drive power source 16 through signal lines 14 and 15. When a specific voltage is applied between signal lines 14 and 15, an electric field is generated in the laminate layer direction in each ceramic thin plate 11 interposed between the electrodes 12 and 13, and every second electric field is in the same direction. Accordingly, each ceramic thin plate 11 is laminated such that the polarization direction of every second thin plates 11 are identical (i.e., the polarization direction of two adjacent ceramic thin plates 11 are opposite). A protective layer 17 is provided at the bilateral ends of the laminate-type piezoelectric element 10.

When a direct current drive voltage from the drive power source 16 is applied between the electrodes 12 and 13, all ceramic thin plates 11 extend or contract in the same direction, so as to extend or contract the entire piezoelectric element 10. When the electric field is small, the displacement of the piezoelectric element 10 and the electric field generated between the electrodes 12 and 13 can be viewed as a nearly linear relationship in the region wherein displacement hysteresis can be ignored. This condition is shown in FIG. 2. In the drawing, the horizontal axis represents the electric field strength, and the vertical axis represents the distortion ratio.

When an alternating current drive voltage (AC signal) from the drive power source 16 is applied between the electrodes 12 and 13, the ceramic thin plates 11 repeatedly extend and contract in the same direction in accordance with the electric field, such that the entire piezoelectric element 10 repeatedly extends and contracts. The piezoelectric element 10 has an intrinsic resonance frequency determined by the electrical characteristics and structure of the piezoelectric element. When the frequency of the alternating current driver voltage and the resonance frequency of the piezoelectric element 10 match, impedance is reduced, and the displacement of the piezoelectric element 10 is increased. The piezoelectric element 10 desirably uses the this resonance phenomenon to drive at low voltage for small displacement relative to the external dimensions of the piezoelectric element 10.

The structure of the truss-type actuator (hereinafter, referred to simply as "actuator") of the present embodiment is shown in FIG. 3. As shown in FIG. 3, the two displacement elements (laminate-type first piezoelectric element and second piezoelectric element) 10 and 10' are arranged so as to intersect at an approximate right angle, and a tip member 20 is cemented with adhesive to the ends on the intersection side. On the other hand, the other ends of the first and second piezoelectric elements 10 and 10' are cemented with adhesive to a base 30. The tip member 20 is desirably formed of tungsten or the like having excellent wear resistance so as to a obtain stable and high friction coefficient. The base 30 is desirably formed of stainless steel or the like having excellent strength and easily manufactured. The adhesive is desirably an epoxy resin or the like having excellent strength and adhesion. The first piezoelectric element 10 and the second piezoelectric element 10' are essentially identical to the piezoelectric element 10 shown in FIG. 1, and the various

structural elements of the second piezoelectric element 10' are differentiated by appending the symbol (') thereto.

The tip 20 performs an elliptic movement by driving the first and second piezoelectric element 10 and 10' with alternating current signals having a phase difference. When the tip 20, for example, is pressed against the exterior surface of a rotor 40 which is rotatable about a specific axis, the elliptic movement (including circular movement) of the tip 20 can be converted to a rotational movement of the rotor 40. Furthermore, the elliptic movement of the tip 20 can be converted to linear movement of a rod-like member, for example, by the tip 20 pressing against the flat surface of the end of a rod (not illustrated). The material of the rotor 40 is desirably a light-weight metal such as aluminum or the like, and the surface of the rotor 40 is desirably subjected to processing such as aluminum anodizing process or the like to prevent wear caused by friction with the tip 20.

The block structure of the drive circuit is shown in FIG. 4. An oscillator 50 generates (oscillates) sine wave signals at a resonance frequency matching the same phase mode and the opposite phase mode, as previously described. A phase controller 51 controls a delay circuit 52 in accordance with the rotation speed, drive torque, and rotation direction of the rotor 40, i.e., the driven member, so as to generate a sine wave signal of shifted phase. An amplitude controller 53 controls a first amplifier 54 and a second amplifier 55 so as to amplify the amplitude of the two sine wave signals having mutually shifted phases. The sine wave signals amplified by the first amplifier 54 and the second amplifier 55 are respectively applied to the first piezoelectric element 10 and the second piezoelectric element 10'.

The drive signals for driving the first piezoelectric element 10 and the second piezoelectric element 10' are described below. When the two intersecting and independent movements are combined, the

intersection point describes a path in accordance with a system of elliptic movement (Lissajous system). In the actuator of the present embodiment, various paths may be described by changing the amplitude (voltage) and phase difference of the drive signal used to drive the first piezoelectric element 10 and the second piezoelectric element 10'. FIGS. 5a~5e show the paths when the amplitude of the of each drive signal is equalized, and the phase difference between each drive signal is 0°, 45°, 90°, 135°, and 180°.

In this way the rotation direction, rotation speed, and rotation force (torque) of the rotor 40 and the like can be controlled by controlling the path of the tip 20. Specifically, if the diameter of the path of the tip 20 is enlarged in a tangent direction relative to the rotor 40, the rotation speed of the rotor 40 increases. Furthermore, if the diameter of the path of the tip 20 is enlarged in a normal line direction relative to the rotor 40, the rotation force of the rotor 40 is increased. If the phase is inverted, the rotation direction can be reversed.

A prototype of the actuator shown in FIG. 3 was actually produced, and tested to determine optimum drive conditions. First, FIGS. 6a~6e show the paths of the tip when the actuator is driven at different voltages with the actuator in a non-load condition (tip 20 and rotor 40 not in contact). The relationship between the voltage of the drive signal applied to the piezoelectric elements 10 and 10' and the diameter (amount of displacement) of the path of the tip 20 is shown in FIG. 6f. The relationship between force applied by the spring 41 and the contact interval of the tip 20 and the rotor 40 is shown in FIG. 7.

FIG. 6a shows the path when a drive signal of amplitude (voltage) 30 V is applied to piezoelectric elements 10 and 10'; FIG. 6b shows the path at 40 V; FIG. 6c shows the path at 50 V; FIG. 6d shows the path at 60 V; FIG. 6e shows the path at 70 V. FIG. 6f shows the voltage-to-

displacement characteristics (i.e., amount of displacement dX in the X direction). As can be understood from the drawings, in the range of drive signal voltages 30 V to 70 V, the voltage of the drive signal of the piezoelectric elements 10 and 10' and the amount of displacement of the tip 20 are near proportional.

In FIG. 7, the vertical axis represents the contact ratio which is a ratio of the contact interval, during which the tip 20 is in contact with the rotor 40, to the entire time period, and the horizontal axis represents the to the compression force of the spring 41. When the voltage (drive signal amplitude) is 70 V, the contact interval between the tip 20 and the rotor 40 is near proportional to the compression force of the spring 41. When the voltage is 70 V, the amount of displacement of the piezoelectric elements 10 and 10' becomes large, and the speed of the tip 20 increases due to the elastic deformation speed (recovery speed) of the rotor 40 and tip 20 through the reaction force of the pressure applied by the spring 41, such that the tip 20 is completely separated from the rotor 40. As the compression force applied by the spring 41 increases, the recovery speed of the tip 20 and rotor 40 increases, and the time during which the tip 20 is separated from the rotor 40 becomes shorter.

In contrast, when the voltage is 50 V and 30 V, the amount of displacement of the piezoelectric elements 10 and 10' is small, and the recovery speed of the tip 20 and the rotor 40 becomes faster via the reaction force to the compression force applied by the spring 41, such that the tip 20 and the rotor 40 are in a state of normal contact. Comparing the two voltages, when the voltage is 30 V, there is less displacement of the piezoelectric elements 10 and 10', and the range of normal contact interval of the tip 20 and the rotor 40 is wider since the speed of the tip 20 is slower. For example, in the case of a voltage of 50 V, the transition point of

-11-

the intermittent contact state and the normal contact state of the tip 20 and the rotor 40 is near the a compression force of 2.5 N.

Then, the voltage of the drive signals of the piezoelectric elements 10 and 10' were set at 50 V and a frequency of 25 kHz, and the load-to-(rotation) speed characteristics of the rotor 40 were measured while changing the compression force of the spring 41 between 0.5 N to 5 N. The measurement results are shown in FIG. 8. The output characteristics (load-to-drive efficiency characteristics) of the actuator under identical conditions is shown in FIG. 9.

First, we focus on the vertical axis (when the load is zero) in FIG. 8. In a non-load state, the speed V is decreased in accordance with an increase in the compression force of the spring 41 from 0.5 N to 5 N. However, in the state of intermittent contact between the tip 20 and the rotor 40, i.e., when the compression force of the spring 41 has the characteristics curve of 0.5 N, 1 N, 1.5 N, and 2 N, the friction force increases between the tip 20 and the rotor 40 in accordance with the increase in compression force by the spring 41, and the starting force (acceleration) of the actuator increases. As can be understood from FIG. 7, the time of contact between the tip 20 and the rotor 40 increases in accordance with the increase in the compression force of the spring 41. Although there is deceleration during the contact between the tip 20 and the rotor 40, the influence of the increase in the starting speed is greater than the influence of this deceleration. As a result, the output of the actuator increases.

On the other hand, in the state of normal contact between the tip 20 and the rotor 40, i.e., when the compression force of the spring 41 has the characteristics curve of 3 N, 4 N, and 5 N, the friction force increases between the tip 20 and the rotor 40 in accordance with the increase in the compression force of the spring 41, such that there is

-12-

increased acceleration of the actuator, however, there is also a simultaneous increase in deceleration. Since the voltage of the drive signal is fixed at, for example, 50 V, the amplitude of the displacement of the piezoelectric elements 10 and 10' is constant, and the difference between the deceleration force (equivalent to torque) is early constant. However, as a result the actuator is reduced due to a reduction in speed when the compression by the spring 41 increases.

Considering the aforesaid conditions in FIG. 8 and focusing on the characteristics curve of a compression force of 2 N and 3 N in FIG. 9, it can be understood that the optimum actuator drive efficiency occurs when the transition point of a state of intermittent contact between the tip 20 and the rotor 40 and the normal contact state is in the vicinity of a compression force of 2.5 N. In the case of this actuator, the condition of maximum drive efficiency η is simultaneously the condition of maximum actuator output since the electrical input is constant.

Next, the test results were analyzed using an elastic contact model producing elastic deformity in the contact area of the tip 20 and the rotor 40. The elastic contact model is shown in FIG. 10. In FIG. 10, consider a spring having the collective mass of the piezoelectric elements 10 and 10' and the tip 20 and rotor 40. The mass of the piezoelectric elements 10 and 10', and the mass of the tip 20 are added. One end of the rotor 40 and the base 30 are fixed, and one end of the piezoelectric elements 10 and 10' are fixed to the base 30. The spring constant of the spring 41 is designated k1, the mass of the base 30 is designated m1, the spring constant and mass of the combined piezoelectric elements 10, 10' and tip 20 are designated k2 and m2, and the spring constant and mass of the rotor 40 are designated k3 and m3.

The relationship between the displacement of the piezoelectric elements 10 and 10' and the drive force generated by such

displacement is shown in FIG. 11. In the drawing, the vertical axis represents the amount of displacement X of the piezoelectric elements 10 and 10', and the horizontal axis represents the force F generated by the piezoelectric elements. Since the piezoelectric elements 10 and 10' are displaced only an amount X0 when a voltage V0 is applied to the piezoelectric elements 10 and 10', a force $F0=k2 \cdot X0$ is generated at the ends of the piezoelectric elements 10 and 10'. Conversely, in the state wherein a voltage is not applied to the piezoelectric elements 10 and 10', the weight W at that end of the element is such that weight $W=F0$, and the piezoelectric elements 10 and 10' are displaced only -X0 (contracts only X0). The Now assume a spring having a spring constant K is mounted in a state of free length to the piezoelectric elements 10 and 10'. When the amount of displacement when a voltage Vo is applied to the piezoelectric elements 10 and 10' is designated X, and the reaction force from the spring is designated F, the relationships $F0=(K+k2) \cdot X$, and $F=K \cdot X$ obtain. When the value K is removed from these equations, the relationship $X=(F0-F)$ obtains.

The operation when the piezoelectric elements 10 and 10' extend and contract is analyzed below. FIG. 12a shows the state before integration of the piezoelectric elements 10 and 10'; FIG. 12b shows the initial state of the integrated piezoelectric elements 10 and 10'. A pressing force N acts in the system without the application of a voltage to the piezoelectric elements 10 and 10'. Each element contracts in accordance with the spring constant, and the piezoelectric elements 10 and 10' have the same weighted state at one end.

FIG. 12c shows the displacement of the piezoelectric elements 10 and 10' when the voltage applied to the piezoelectric elements 10 and 10' is gradually increased. The spring 41 and rotor 40 (spring component) contract and the compression increases in accordance with the extension of the piezoelectric elements 10 and 10'. The piezoelectric elements 10

-14-

and 10' are identical in that a spring having a spring constant K=K1.K3/(K1+k3) is mounted on one end of the piezoelectric elements 10 and 10'.

FIG. 12d shows the state resulting from a rapid reduction or reversal of the voltage applied to the piezoelectric elements 10 and 10', and the rapid contraction of the piezoelectric elements. In this case, the rotor 40 follows the rapid displacement of the piezoelectric elements 10 and 10', but the base 30 and the spring 41 cannot follow, and only the base 30 is not displaced. Accordingly, in FIG. 12d, the base 30 is at rest as a wall.

When the piezoelectric elements 10 and 10' contract, the spring component of the rotor 40 is extended in conjunction with the contraction of the piezoelectric elements, and the compression force pressing between the rotor 40 and the piezoelectric elements 10 and 10' is reduced. In this case, the spring opposing the piezoelectric elements 10 and 10' is only the spring component (spring constant k3) of the rotor 40, and the spring constant is greater than when the piezoelectric elements 10 and 10' are extended as shown in FIG. 12c (k3>K). Accordingly, when the piezoelectric elements 10 and 10'contract as shown in FIG. 12d, the slope of the displacement-to-generated force characteristics are smaller than when the piezoelectric elements 10 and 10' are extended as shown in FIG. 12c. As a result, the path of the tip 20 provided at the intersection of the two piezoelectric elements 10 and 10' shifts from circular to elliptic.

The relationship of each constant is determined using FIGS. 12a~12d. The compression force in FIGS. 12b, 12c, 12d are designated N, N', N"; the displacement of each element is designated ΔXn, $\Delta Xn'$, $\Delta Xn"$ (where n=1~3). Since the total length of the system is unchanged in these states, the following relationship obtains.

$$\Delta X1 + \Delta X2 + \Delta X3 = \Delta X1' - \Delta X2' + \Delta X3' = \Delta X" + \Delta X2" + \Delta X3" \qquad (1)$$

The following are derived from Hooke's Law.

$$N = \Delta X1 \times k1 = \Delta X2 \times k2 = \Delta X3 \times k3$$

$$N' = \Delta X1' \times k1 = (X0 - \Delta X2') \times k2 = \Delta X3' \times k3$$

$$N'' = \Delta X2'' \times k2 = \Delta X3'' \times k3$$

When N, N', N'' are substituted in the left side of the equality of equation (1), the following is obtained.

$$N(1/k1 + 1/k2 + 1/k3) = N'(1/k1 + 1/k2 + 1/k3) - X0$$

$$N - N' = X0/(1/k1 + 1/k2 + 1/k3) \qquad (2)$$

Similarly, when N, N', N'' are substituted in the right side of equation (1), the following obtains.

$$N'(1/k1 + 1/k2 + 1/k3) - X0 = N'/k1 + N''(1/k2 + 1/k3)$$

$$N' - N'' = X0/(1/k2 + 1/k3) \qquad (3)$$

When N' is eliminated from equations (2) and (3), the following obtains.

$$N - N' = X0(1/(1/k2 + 1/k3) - 1/(1/k1 + 1/k2 + 1/k3))$$

When the critical compression force of the spring 41 at the time of transition from the intermittent contact state to the normal contact state between the tip 20 and the rotor 40 is designated Nt, since N''=0, the following obtains.

$$Nt = X0(1/(1/k2 + 1/k3) - 1/(1/k1 + 1/k2 + 1/k3)) \qquad (4)$$

On the other hand, the amplitude Nw of the compression applied to the rotor 40 is normally constant in the normal contact state between the tip 20 and the rotor 40, such that from equation (3) the following obtains.

$$Nw = N' - N'' = X0/(1/k2 + 1/k3) \qquad (5)$$

At this time the displacement Xt of the piezoelectric elements 10 and 10' is also constant, and that value is expressed below.

$$Xt = \Delta X2' + \Delta X2'' = X0 - N'/k2 + N''/k2 = X0 \, k2/(k2 + k3) \qquad (6)$$

-16-

In order to increase the output of a truss-type actuator such as the present embodiment, the force in the tangent direction of the rotor 40 transmitted to the rotor 40 from the tip 20, i.e., the difference in the acceleration force and deceleration force, may be increased. This force in the tangent direction is expressed as the product of the friction coefficient μ acting between the tip 20 and the rotor 40, and the amplitude Nw of the compression force. Various methods of increasing the friction coefficient μ have been proposed heretofore, and description of these methods are omitted. However, As can be understood from equation (5), increasing the amplitude Nw of the compression force can be achieved by increasing the displacement X0 of the tip 20 or the piezoelectric elements 10 and 10', or increasing the spring constant k2 of the piezoelectric elements 10 and 10' or the spring constant k2 of the spring component of the rotor 40.

The method of increasing the displacement X0 includes methods of simply increasing the amplitude (voltage) of the drive signal applied to the piezoelectric elements q0 and 10', and methods which use the resonance phenomenon to drive the piezoelectric elements 10 and 10' at their respective resonance frequency. In the case of the former method, the drive efficiency is not changed because the energy required to drive the piezoelectric element also increases. In the case of the latter method, the drive efficiency is effectively improved because a large displacement is obtained using little energy.

The combined spring constant k2 of the tip 20 and the piezoelectric elements 10 and 10', and the spring constant k3 of the rotor 40 are determined by the characteristics and shape of the respective members. When the cross section of the piezoelectric elements 10 and 10' and the rotor 40 is designated S, the elasticity of the material of these members is designated E, and their length is designated L, the spring constant k is expressed as k=S·E/L. Accordingly, the spring constants k2 and

-17-

k3 can be increased by increasing the cross sections S and reducing the length L of the piezoelectric elements 10 and 10', tip 20, and rotor 40, and the elasticity E of the material of these members, with the result that the output of the actuator can be increased.

Since the spring constant k3 of the rotor 40 changes depending on the surface roughness and hardness of the contact surface of the tip 20, may be made smooth by polishing the surfaces of the tip 20 and rotor 40, and increasing the hardness of the surface by a nitriding process or oxidation process.

Although a piezoelectric element is used as the displacement element in the present embodiment, piezoelectric elements generally are made of ceramic material which increase the attenuation of the oscillation compared to metal material, and have a small displacement expansion ratio during resonance. Although ceramic is strong relative to compression force, it is weak relative to tension force, and there is a possibility of peeling at the cemented surface particularly in the case of laminate-type piezoelectric elements. An element formed by a single layer piezoelectric element and a metal elastic body connected in series may be used as the displacement element. The structure of a truss-type actuator using such a displacement element is shown in FIG. 14.

A first displacement element 60 and second displacement element 61 respectively comprise a single layer piezoelectric element (ceramic thin plate) 61 and 61', and elastic body 61, 62', and electrodes are not provided on both surfaces of the piezoelectric elements 61 and 61'. The first displacement element 60 and the second displacement element 60' are attached to the tip 20 and base 30 by bolts 63 and 63' without using adhesive. The elastic bodies 62 and 62' and the base 30 are respectively formed of electrically conductive material, drive power sources 16 and 16' are connected between the elastic bodies 62, 62' and the base 30, so as

to drive the first displacement element 60 and the second displacement element 60' at the previously described resonance frequency.

Displacement can be magnified by resonating the elastic bodies 62 and 62' using the piezoelectric elements 61 and 61' as the oscillation source. Displacement is greater because of the small attenuation of the metal material, and it is possible to prevent damage to the piezoelectric elements 61 and 61' by reducing the tension force added to the piezoelectric elements 61 and 61'. Aluminum, titanium, iron, copper and alloys thereof may be used as the material for the elastic bodies 62 and 62'. The proportion of the entire displacement element of the single layer piezoelectric elements 61 and 61' is extremely small in the length direction.

Although two displacement elements 10 and 10' or 60 and 60' are arranged so as to intersect in order to drive the tip 20 in the description of the present embodiment, the present invention is not limited to this arrangement inasmuch as these displacement elements also may be arranged at other optional angles, e.g., 45°, 135° and the like. Furthermore, the number of displacement elements is not limited to two, inasmuch as three or more displacement elements may be used, so as to drive the displacement elements with three or four degrees of freedom. The drive source of the displacement element need not be only a piezoelectric element, since other electrical or mechanical displacement elements may be used, such as a magnetostrictive element and the like.

As described above, the present invention drives a displacement element when the tip member is on contact with the rotor, and near conditions of transition from an intermittent contact state to a normal contact state.

When the drive member (e.g., tip member 20) and the driven member (e.g., rotor 40) are in a state of intermittent in contact, the friction

force acting between the drive member and the driven member increases in conjunction with increase in compression force by the compression member (e.g., spring 41), thereby increasing the starting force (acceleration) of the actuator. Furthermore, the time of contact between the drive member and the driven member lengthens in conjunction with the increase in the compression force by the compression member. Since the increase in acceleration is greater than the deceleration during contact between the drive member and the driven member, the actuator output is increased.

On the other hand, when the drive member and the driven member are in a state of normal contact, the friction force acting between the drive member and the driven member increase in conjunction with the increase in compression force by the compression member, so as to produce an increase in the starting force of the actuator, but the deceleration force also increases simultaneously. When the voltage of the drive signal is fixed, the amplitude of the displacement of the displacement element is constant, and the difference between acceleration force and deceleration force (equivalent to torque) is nearly constant. Since the speed is reduced when the compression force of the compression member increases, there is a resulting reduction in the output of the actuator.

Accordingly, the actuator drive efficiency can be maximized and the actuator output can be simultaneously maximized by driving the displacement element the drive member and driven member are in a state of intermittent contact, and in a state near the condition of transition from the intermittent contact state to the normal contact state.

When the spring constant of the compression member is designated k1, the spring constant of the displacement member is designated k2, the spring constant of the combined drive member and

-20-

driven member is designated k3, the amount of displacement of the displacement element is designated X0, and the compression force of the compression member is designated Nt, the actuator can be driven under critical conditions by satisfying the relationship below.

$$Nt=X0(1/(1/k2+1/k3)-1/(1/k1+1/k2+1/k3))$$

The amount of displacement X0 of the displacement element can be increased without increasing the drive voltage of the displacement element by driving the displacement element at a resonance frequency.

Although the present invention has been fully described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modification will be apparent to those skilled in the art. Therefore, unless otherwise such changes and modifications depart from the scope of the present invention, they should be construed as being included therein.

What is claimed is:

1   1.   An actuator for moving a driven member, said actuator
2   comprising:
3   a displacement element for producing a specific
4   displacement;
5   a drive member connected to one end of said displacement
6   element and which transfers the displacement of said displacement
7   element to a driven member;
8   a stationary member which supports the other end of the
9   displacement element;
10   a compression member for pressing said drive member against
11   the driven member; and
12   a drive circuit for driving said displacement element such that
13   the drive member and the driven member are in a state of intermittent
14   contact under conditions near the condition of transition from the
15   intermittent contact state to a normal contact state.

1   2.   An actuator as claimed in claim 1, wherein a following
2   relationship is satisfied:
3              $Nt=X0(1/(1/k2+1/k3)-1/(1/k1+1/k2+1/k3))$
4   when the spring constant of the compression member is
5   designated k1, the combined spring constant of the displacement element
6   and the drive member is designated k2, the spring constant of the driven
7   member is designated k3, the amount of displacement of the
8   displacement element is designated X0, and the compression force
9   applied by the compression member is designated Nt.

-22-

1   3.   An actuator as claimed in claim 2, wherein said drive circuit

2   drives said displacement element at a resonance frequency.

1   4.   An actuator as claimed in claim 1, wherein said drive circuit

2   drives said displacement element at a resonance frequency.

1   5.   An actuator as claimed in claim 1, wherein said displace

2   element is a laminate-type piezoelectric element.

1   6.   An actuator as claimed in claim 5, wherein said displace

2   element includes alternating layers of a plurality of piezoelectric thin plates

3   and electrodes.

1   7.   An actuator for moving a driven member, said actuator

2   comprising:

3   a first displacement element for producing a specific

4   displacement;

5   a second displace element for producing a specific

6   displacement of which direction has a predetermined angle to a direction

7   of the specific direction of said first displacement element;

8   a drive member connected to one ends of said first and

9   second displacement elements and which transfers the displacement of

10   said first and second displacement elements to a driven member;

11   a stationary member which supports the other ends of the first

12   and second displacement elements;

13   a compression member for pressing said drive member against

14   the driven member; and

15   a drive circuit for driving said first and second displacement

16   elements such that the drive member and the driven member are in a

17 state of intermittent contact under conditions near the condition of

18 transition from the intermittent contact state to a normal contact state.

1 8.   An actuator as claimed in claim 7, wherein a following

2 relationship is satisfied:

3          $Nt=X0(1/(1/k2+1/k3)-1/(1/k1+1/k2+1/k3))$

4   when the spring constant of the compression member is

5 designated k1, the combined spring constant of the first and second

6 displacement elements and the drive member is designated k2, the spring

7 constant of the driven member is designated k3, the amount of

8 displacement of the first and second displacement elements is designated

9 X0, and the compression force applied by the compression member is

10 designated Nt.

1 9.   An actuator as claimed in claim 8, wherein said drive circuit

2 drives said first and second displacement elements at a resonance

3 frequency.

1 10.   An actuator as claimed in claim 7, wherein said drive circuit

2 drives said first and second displacement elements at a resonance

3 frequency.

1 11.   An actuator as claimed in claim 7, wherein each of said first

2 and second displace elements is a laminate-type piezoelectric element.

1 12.   An actuator as claimed in claim 11, wherein each of said first

2 and second displace elements includes alternating layers of a plurality of

3 piezoelectric thin plates and electrodes.

-24-

ABSTRACT OF THE DISCLOSURE

Piezoelectric elements 10 and 10' are driven so as to satisfy the relationship

$$Nt=X0(1/(1/k2+1/k3)-1/(1/k1+1/k2+1/k3))$$

when the drive member, tip 20, and driven member, rotor 40, are in a state of intermittent contact, and in a state near the condition of transition from the intermittent contact state to the normal contact state. When the spring constant of the spring 41 is designated k1, the spring constant of the combined piezoelectric elements 10 and 10' and the tip 20 is designated k2, the spring constant of the rotor 40 is designated k3, the amount of displacement of the piezoelectric elements 10 and 10' is designated X0, and the compression force of the spring 41 is designated Nt.
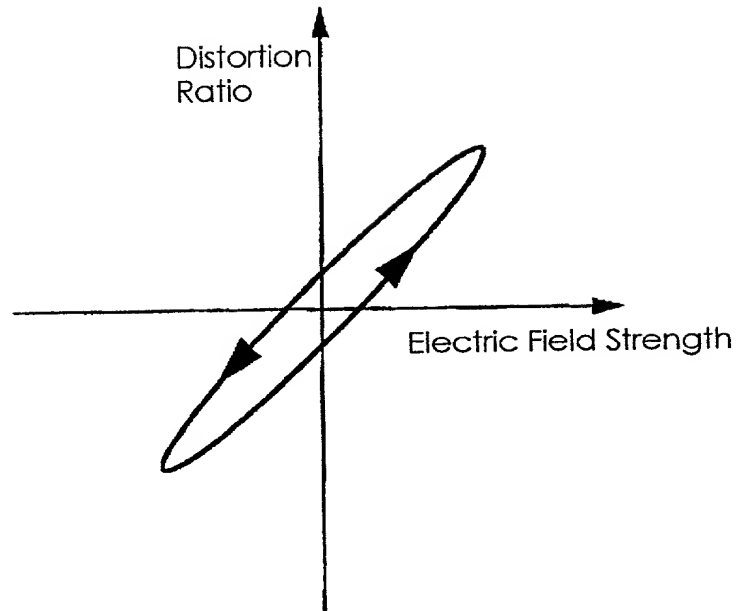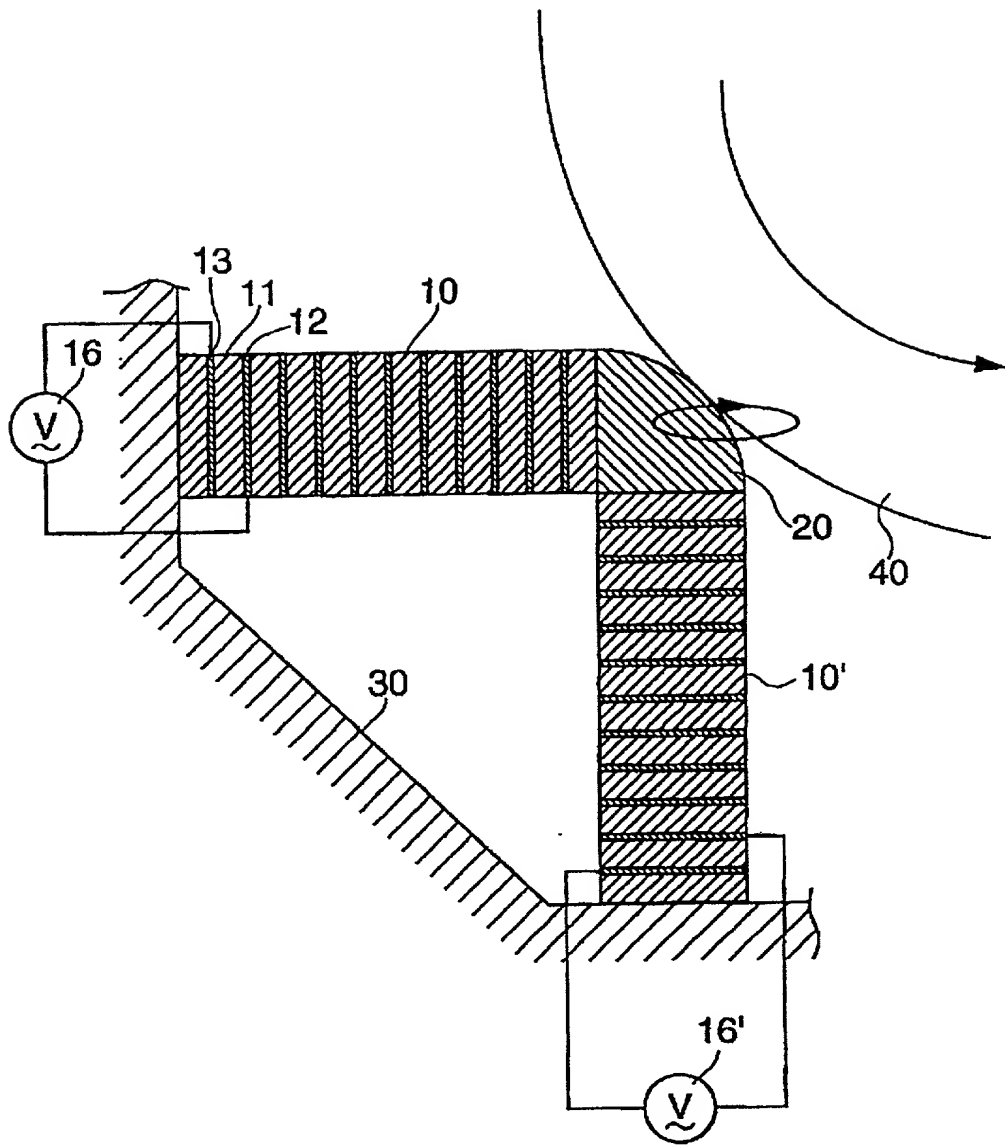
5

10

-25-

FIG. 1

FIG. 2

FIG. 3

FIG. 4

Oscillator — 50

Phase Controller — 51

Delay Circuit — 52

1st Amplifier — 54

Amplitude Controller — 53

2nd Amplifier — 55

1st Piezoelectric Element — 10

2nd Piezoelectric Element — 10'

FIG. 5a

Phase Difference: 0°

FIG. 5b

Phase Difference: 45°

FIG. 5c

Phase Difference: 90°

FIG. 5d

Phase Difference: 135°

FIG. 5e

Phase Difference: 180°

FIG. 6a

(30V)

FIG. 6b

(40V)

FIG. 6c

(50V)

FIG. 6d

(60V)

FIG. 6e

(70V)

FIG. 6f

Voltage-to-displacement
Characteristic
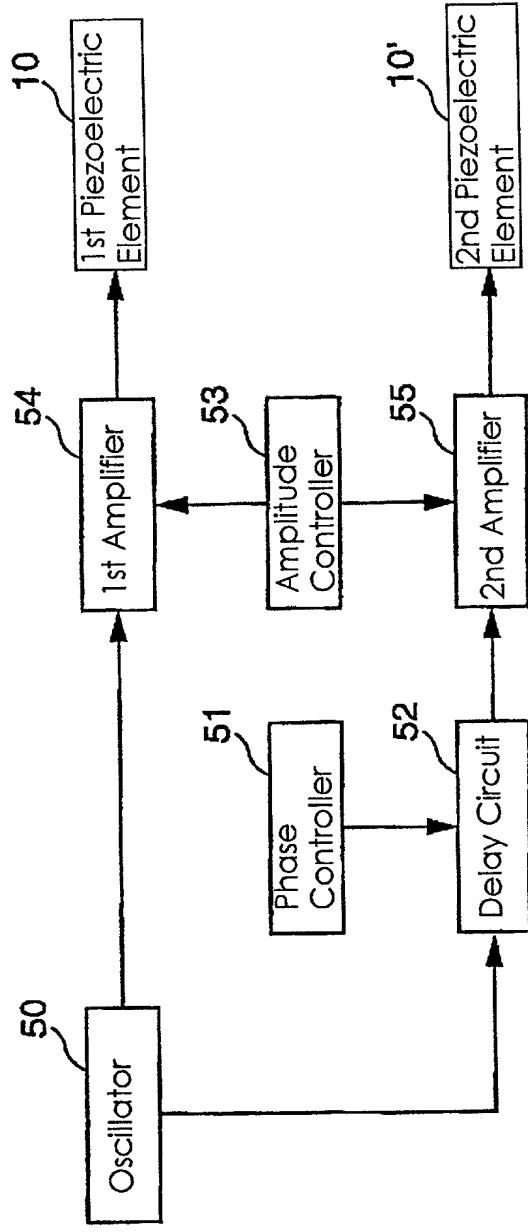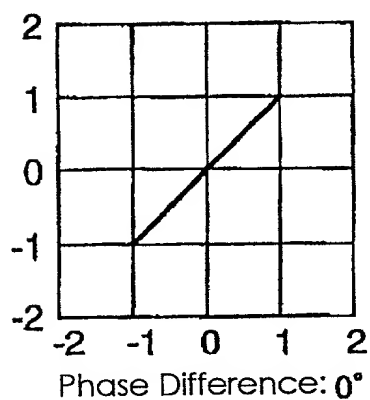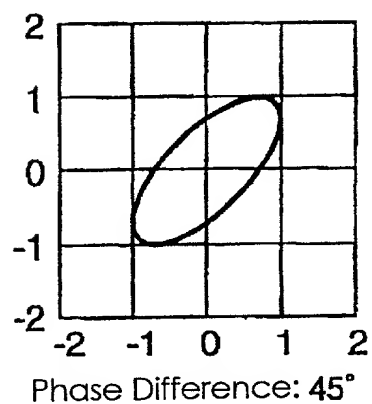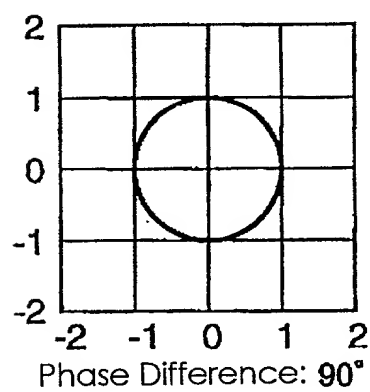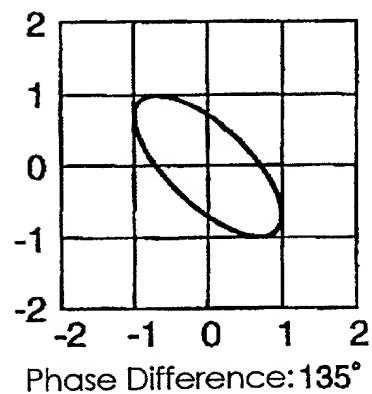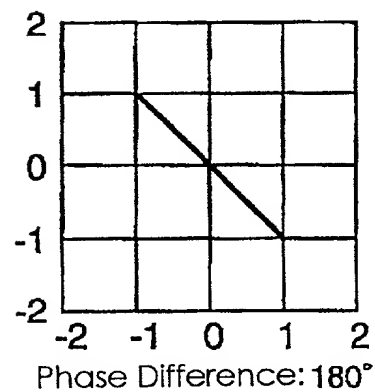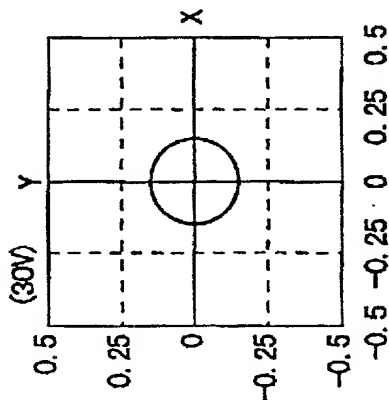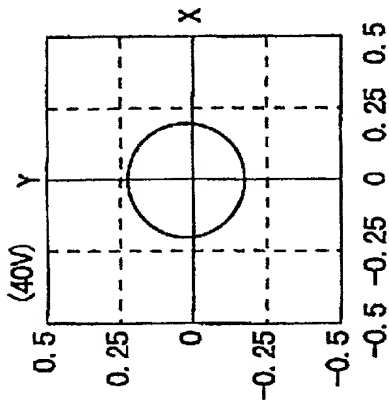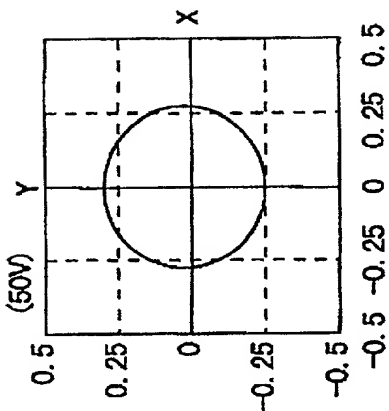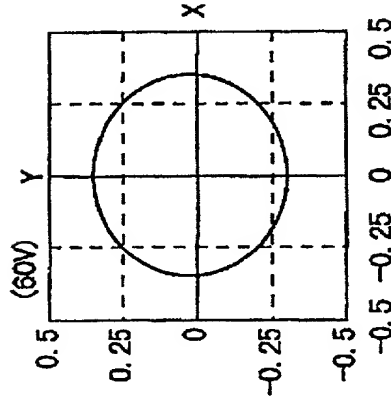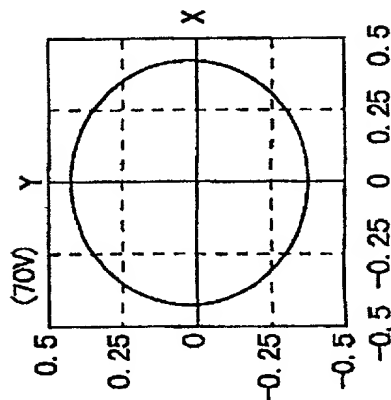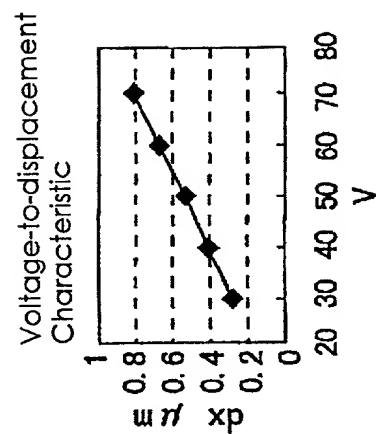
FIG. 7

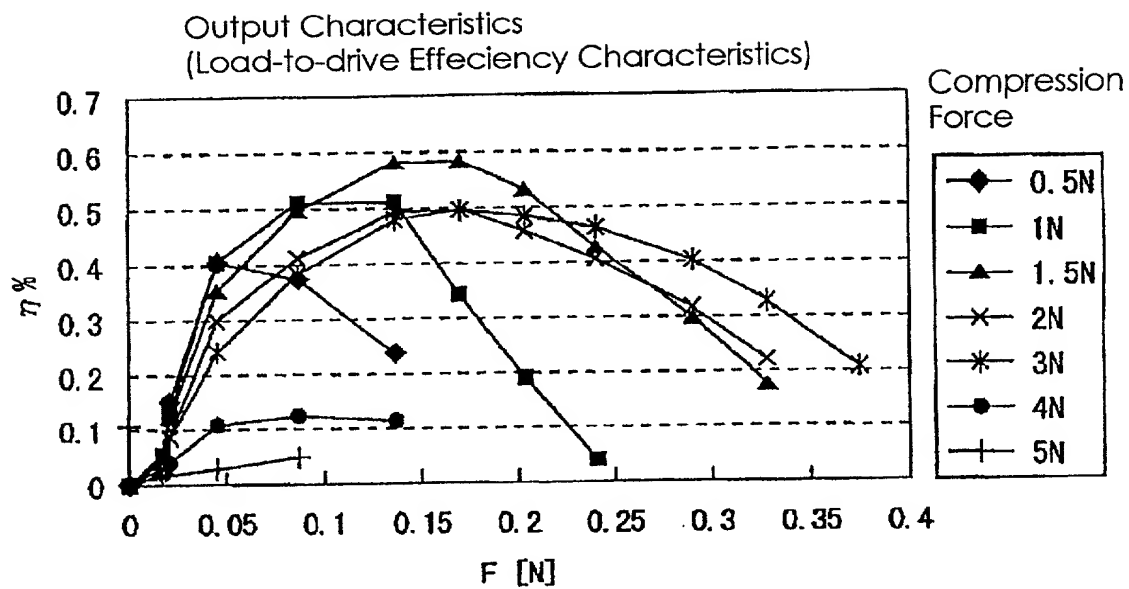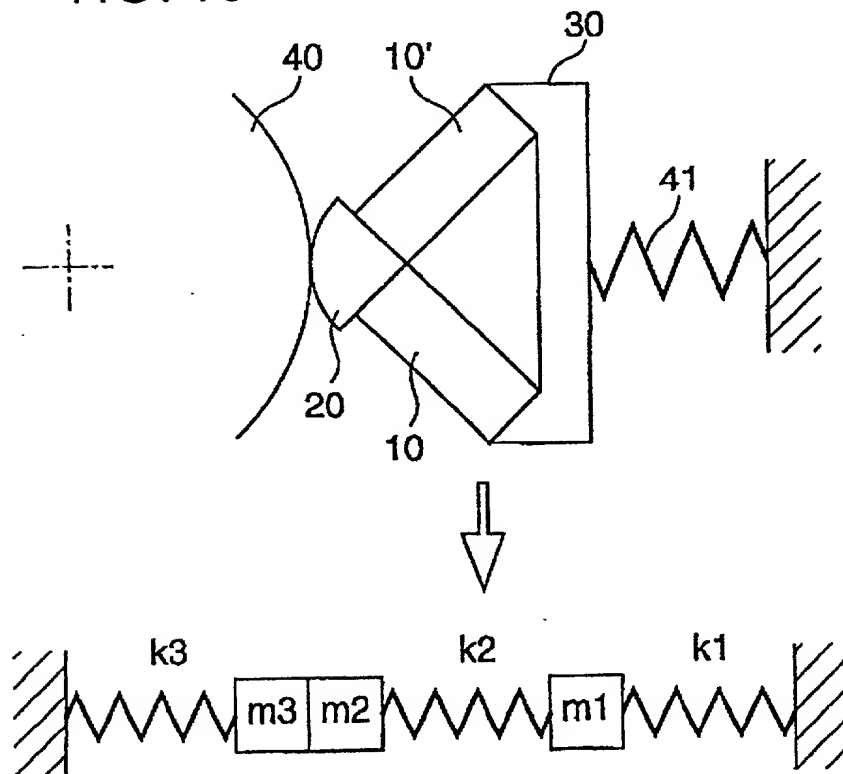Relationship between Compression Force and Contact Interval
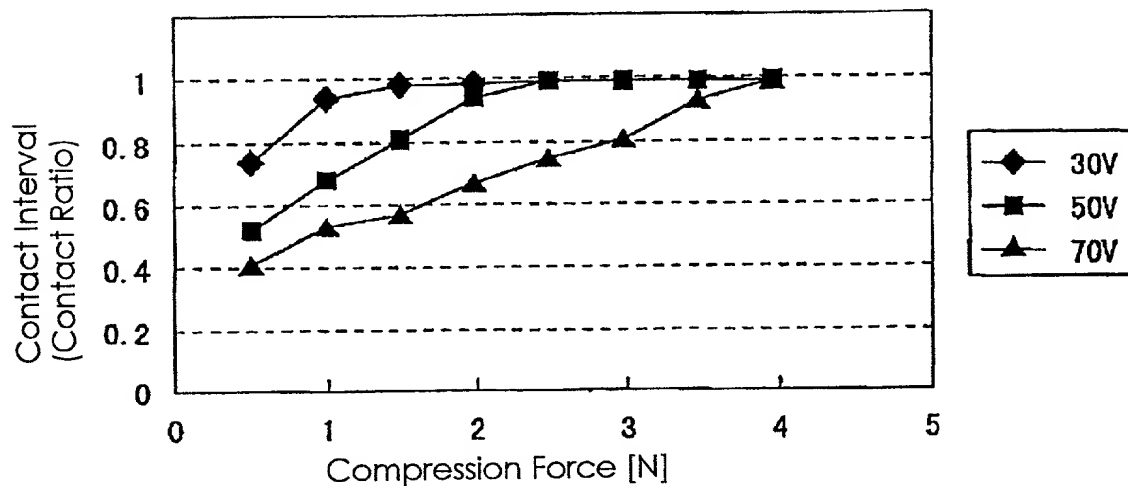
FIG. 8

FIG. 9

Output Characteristics
(Load-to-drive Effeciency Characteristics)

Compression Force

- ◆ 0.5N
- ■ 1N
- ▲ 1.5N
- × 2N
- ✳ 3N
- ● 4N
- + 5N

FIG. 10

FIG. 11

Amount of Displacement

$X0$

X

$X=(F0-F)/k2$

F

$F0$

Force

Weight

$-X0$

FIG. 12a

k2

m2

k3   k1

m3   m1

ΔX3   ΔX1

FIG. 12b

ΔX2

N

ΔX3'   ΔX1'

FIG. 12c

F0   ΔX2'

N'

ΔX3''

FIG. 12d

ΔX2''   V=0

N''

FIG. 13

FIG. 14

FIG. 15

FIG. 14

Amount of Displacement (Voltage)

Time

1st Piezoelectric Element

2nd Piezoelectric Element
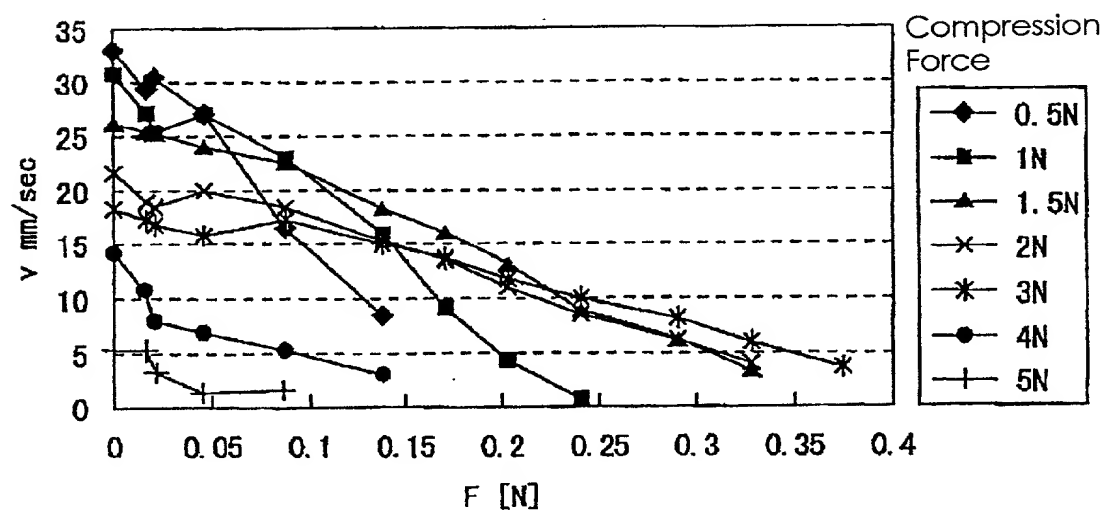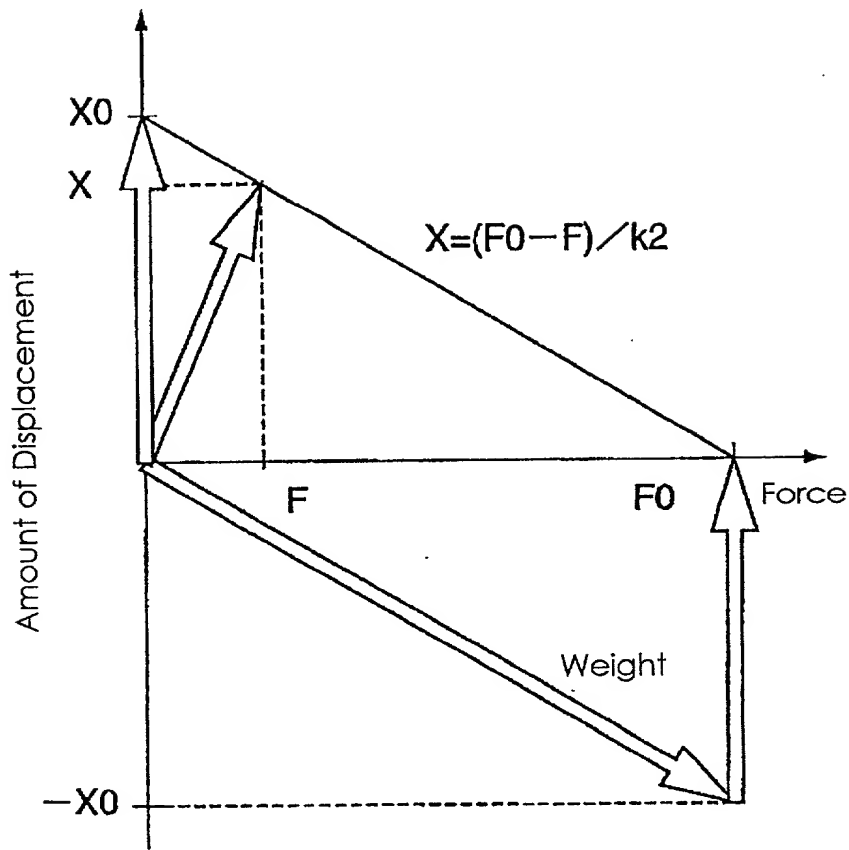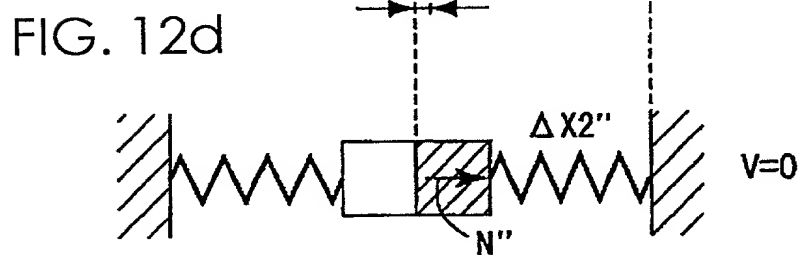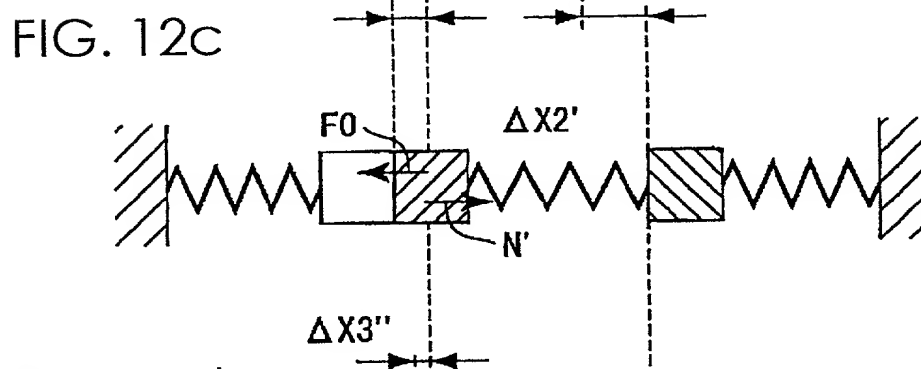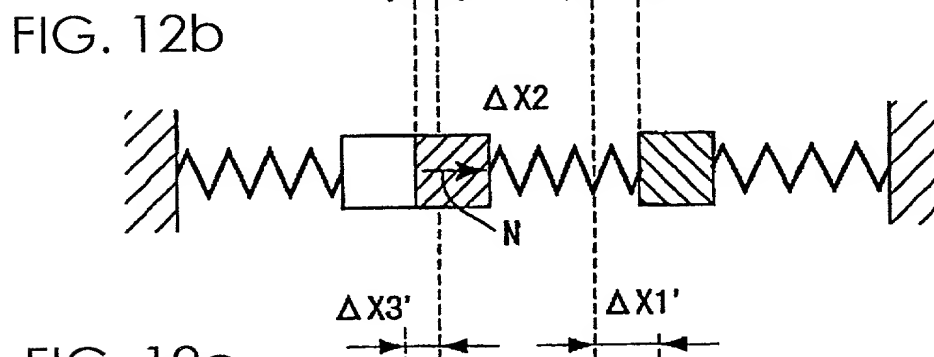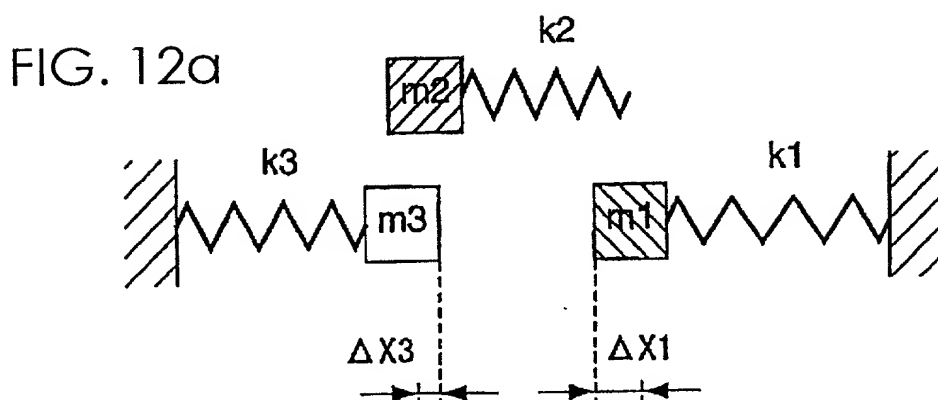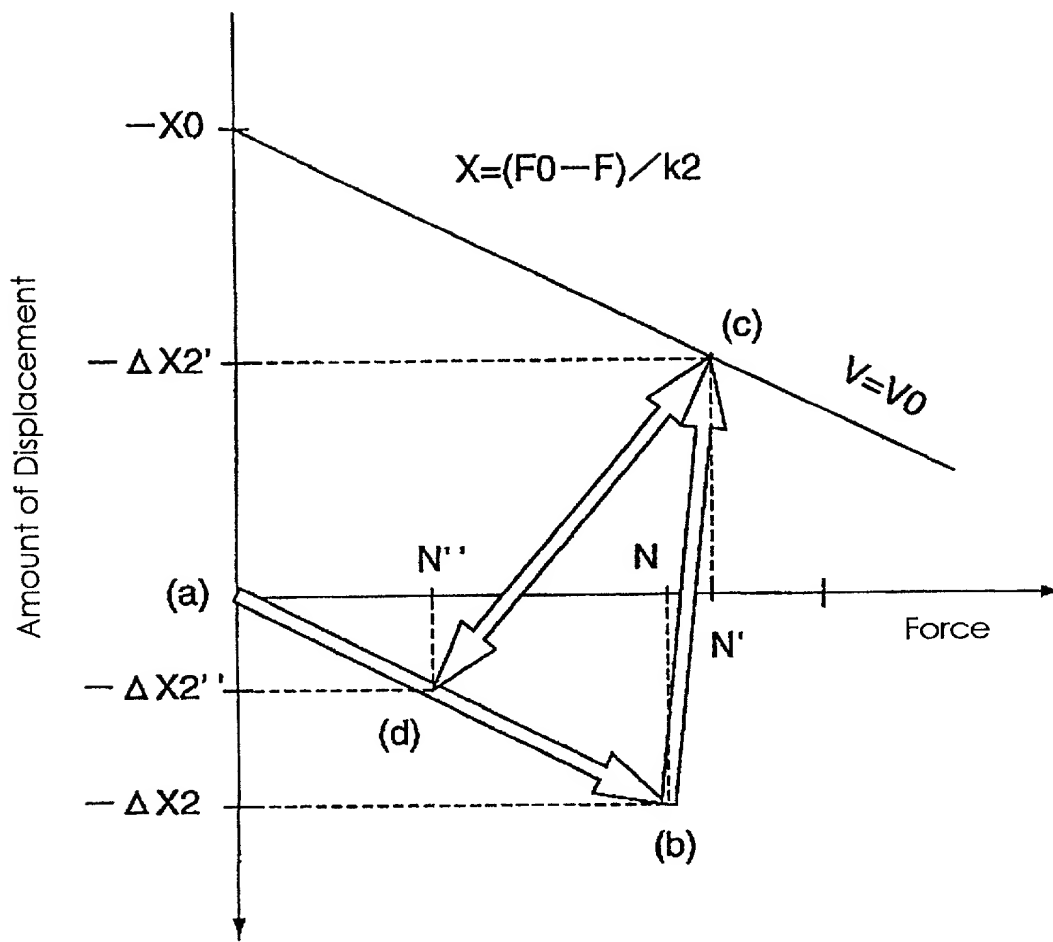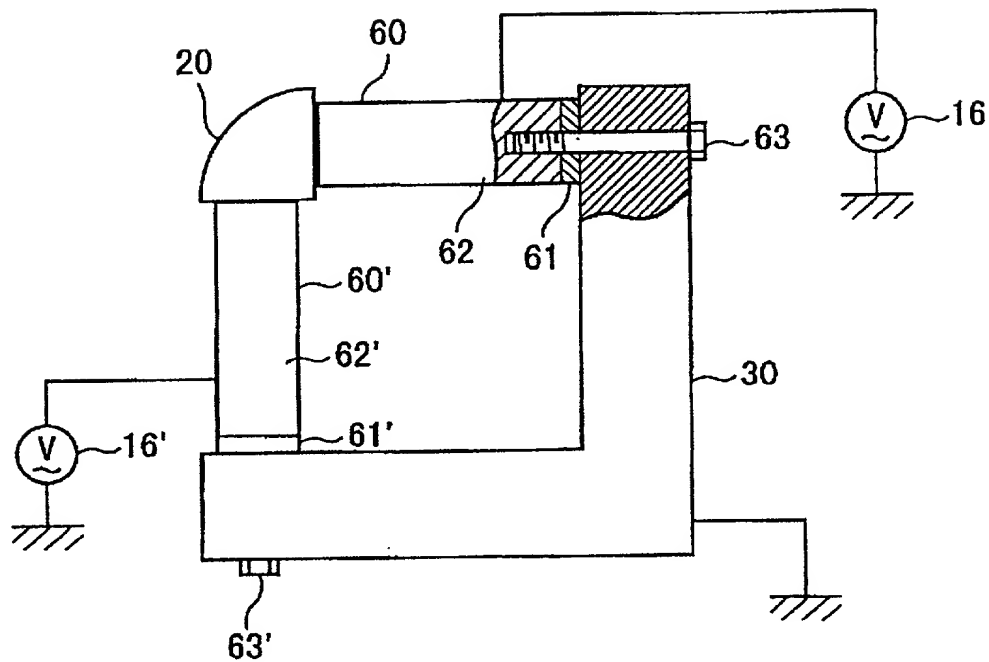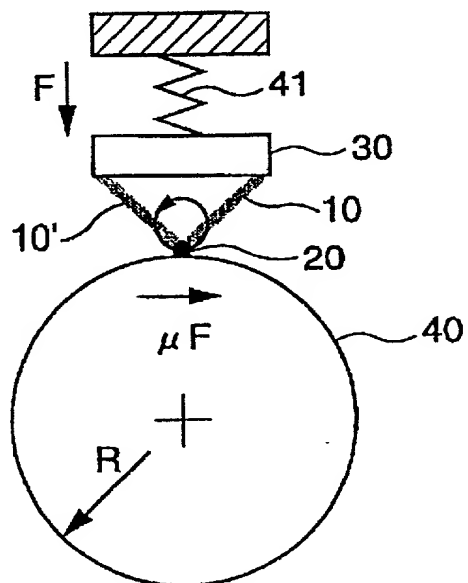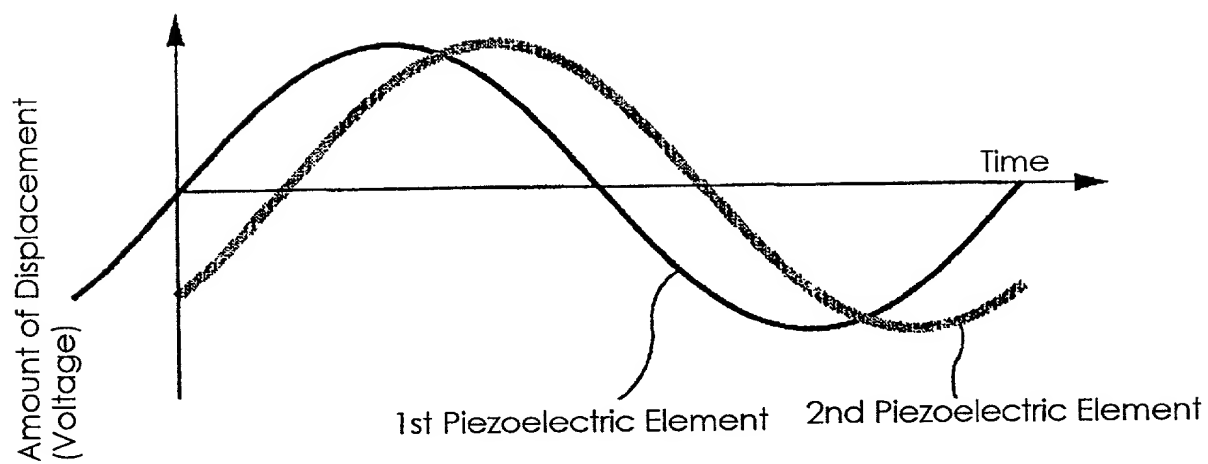
FIG. 17a   FIG. 17b   FIG. 17c   FIG. 17d   FIG. 17e
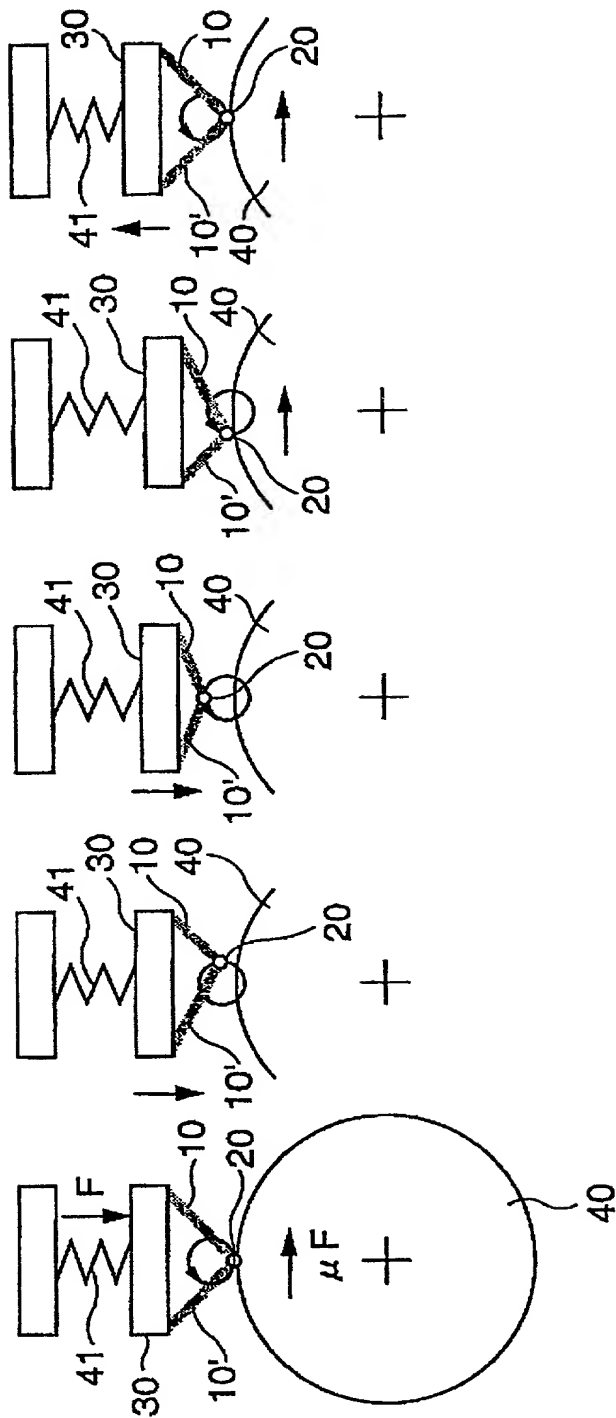
代理人の案件番号:

Attorney Docket No.:

特許出願宣誓書および委任状	**DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION**

私は、以下に記載された発明者として、ここに下記の通り宣言する：

As a below named inventor, I hereby declare that:

私の住所、郵便の宛先、国籍は、私の氏名の後に記載された通りである。

My residence, post office address, and citizenship are as stated next to my name.

下記の名称の発明について、特許請求の範囲に記載され、かつ特許が求められている発明主題に関して、私は、私が最初、最先かつ唯一の発明者である（唯一の氏名が記載されている場合）か、または、私と以下に記載された他の者が最初、最先かつ共同発明者である（複数の氏名が記載されている場合）と、信じている。

I believe that I am the original, first, and sole inventor (if only one name is listed below) or I and the other person(s) listed below are the original, first, and joint inventors (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

ACTUATOR USING DIPPLACEMENT ELEMENT

上記発明の明細書はここに添付されているが、下記のボックスがチェックされている場合は、この限りでない：

the specification of which is attached hereto unless the following box is checked:

☐ 上記発明が、以下の日に出願され、

☐ was filed on

以下の米国出願番号を有し、

as United States Application Number

または、以下のＰＣＴ国際出願番号を有し、

or PCT International Application Number

かつ、以下の日に補正されている   and was amended on

（該当する場合）。   (if applicable).

私は、上記の補正書によって補正された、特許請求の範囲を含む上記明細書を検討し、かつ内容を理解していることをここに表明する。

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第３７編規則１．５６に定義されている、特許性について重要な情報を開示する義務があることを認める。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

私は、ここに、以下に記載した外国での特許出願または発明者証の出願、或いは米国以外の少なくとも一国を指定している米国法典第３５編第３６５条(a)項によるＰＣＴ国際出願について、同第１１９条(a)-(d)項または第３６５条(b)項に基づいて優先権を主張するとともに、優先権を主張する本出願の出願日よりも前の出願日を有する外国での特許出願または発明者証の出願、或いはＰＣＴ国際出願については、いかなる出願も、下記のボックスをチェックすることにより示した。

I hereby claim foreign priority under Title 35, United States Code, Section 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT international application having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)
(外国での先行出願)

<div style="text-align: right">

Priority
Not Claimed
(優先権主張なし)
</div>

11-312965	Japan	2 / 11 / 1999	☐
(Number)	(Country)	(Day/Month/Year Filed)	
(番号)	(国名)	(出願日/月/年)	

			☐
(Number)	(Country)	(Day/Month/Year Filed)	
(番号)	(国名)	(出願日/月/年)	

			☐
(Number)	(Country)	(Day/Month/Year Filed)	
(番号)	(国名)	(出願日/月/年)	

			☐
(Number)	(Country)	(Day/Month/Year Filed)	
(番号)	(国名)	(出願日/月/年)	

			☐
(Number)	(Country)	(Day/Month/Year Filed)	
(番号)	(国名)	(出願日/月/年)	

			☐
(Number)	(Country)	(Day/Month/Year Filed)	
(番号)	(国名)	(出願日/月/年)	

			☐
(Number)	(Country)	(Day/Month/Year Filed)	
(番号)	(国名)	(出願日/月/年)	

私は、ここに、下記のいかなる米国仮特許出願についても、その米国法典第３５編１１９条(e)項の利益を主張する。

I hereby claim the benefit under Title 35, United States Code, Section 119(e) of any United States provisional application(s) listed below.

(Application Number) (出願番号)		(Filing Date) (出願日)

(Application Number) (出願番号)		(Filing Date) (出願日)

私は、ここに、以下のいかなる米国出願についても、その米国法典３５編第１２０条に基づく利益を主張し、また米国を指定するいかなるＰＣＴ国際出願についても、その同第３６５条(c)項に基づく利益を主張する。また、本出願の各特許請求の範囲の主題が、米国法典第３５編第１１２条第１段に規定された態様で、先行する米国出願またはＰＣＴ国際出願に開示されていない場合においては、その先行出願の出願日と本国内出願日またはＰＣＴ国際出願日との間の期間中に入手された情報で、連邦規則法典第３７編規則１．５６に定義された特許性に関わる重要な情報について開示義務があることを承認する。

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT international application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of application.

(Application Number) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現状：特許許可、係属中、放棄)

(Application Number) (出願番号)	(Filing Date) (出願日)	(Status: Patented, Pending, Abandoned) (現状：特許許可、係属中、放棄)

私は、ここに表明された私自身の知識に係わる陳述が真実であり、かつ情報と信ずることに基づく陳述が、真実であると信じられることを宣言し、さらに、故意に虚偽の陳述な

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are

どを行なった場合は、米国法典第18編第1001条に基づき、罰金または拘禁、若しくはその両方により処罰され、またそのような故意による虚偽の陳述は、本出願またはそれに対して発行されるいかなる特許も、その有効性に問題が生ずることを理解した上で陳述が行なわれたことを、ここに宣言する。

委任状： 私は、本出願を審査する手続きを行ない、かつ米国特許商標庁との全ての業務を遂行するために、記名された発明者として、以下のカスタマー番号に対応する弁護士・弁理士を任命する。また、私は、全ての連絡はそのカスタマー番号に対応するアドレスになされることを指示する。

Customer Number: 24367

直通電話先：

_____James W. Williams_____

ダイレクトイン：_(214) 981-3328_____

代表電話番号：__(214) 981-3300_____

代理人の案件番号：_____

punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the practitioners associated with the Customer Number provided below to prosecute this application and transact all business in the Patent and Trademark Office connected therewith, and direct that all correspondence be addressed to the address associated with that Customer Number.

24367

PATENT & TRADEMARK OFFICE

Direct telephone calls to:

_____James W. Williams_____

Direct No.:_(214) 981-3328_____

Main No.:__(214) 981-3300_____

Attorney Docket No.:_____

Full name of sole or first joint inventor:
唯一または第1発明者の氏名:

Shinya		MATSUDA
First	Middle	Last
(名)	(ミドルネーム)	(姓)

Inventor's signature: *Shinya Matsuda*
発明者の署名:

Date: *Oct. 17, 2000*
日付:

Residence: Takarazuka-Shi	Hyogo-Ken	Japan
住所: (City)	(Prefecture)	(Country)
(市)	(都道府県)	(国名)

Citizenship: Japan
国籍

Post Office Address: c/o MINOLTA CO., LTD.
郵便の宛先:

Osaka Kokusai Bldg., 3-13, 2-Chome,

Azuchi-Machi, Chuo-Ku, Osaka-Shi,

Osaka 541-8556 JAPAN

Full name of second joint inventor:
第２共同発明者の氏名:

Takashi		MATSUO
First (名)	Middle (ミドルネーム)	Last (姓)

Inventor's signature: *Takashi Matsuo*
発明者の署名:

Date: *Oct. 17, 2000*
日付:

Residence:	Itami-Shi	Hyogo-Ken	Japan
住所:	(City) (市)	(Prefecture) (都道府県)	(Country) (国名)

Citizenship: Japan
国籍

Post Office Address: c/o MINOLTA CO., LTD.
郵便の宛先:

Osaka Kokusai Bldg., 3-13, 2-Chome,

Azuchi-Machi, Chuo-Ku, Osaka-Shi,

Osaka 541-8556 JAPAN

Full name of third joint inventor:
第３共同発明者の氏名：

Masayuki		UEYAMA
First	Middle	Last
（名）	（ミドルネーム）	（姓）

Inventor's signature:___*Masayuki Ueyama*___
発明者の署名：

Date:___*Oct. 17, 2000*___
日付：

Residence:___Takarazuka-Shi___	Hyogo-Ken	Japan
住所： （City)	(Prefecture)	(Country)
（市）	（都道府県）	（国名）

Citizenship:__Japan__
国籍

Post Office Address:___c/o MINOLTA CO., LTD.___
郵便の宛先：

___Osaka Kokusai Bldg., 3-13, 2-Chome,___

___Azuchi-Machi, Chuo-Ku, Osaka-Shi,___

___Osaka 541-8556 JAPAN___